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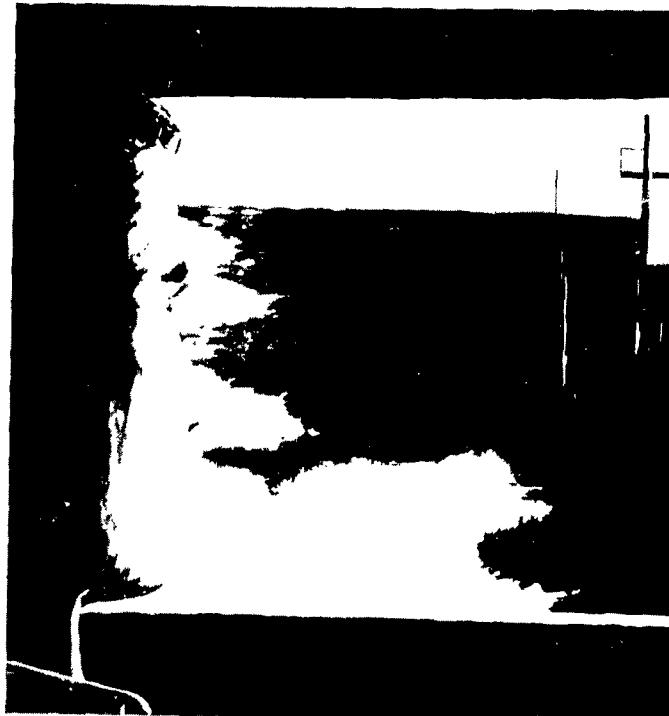
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651
TECHNICAL
REPORT
NO. 7
PRINTED BY DDC
407 NO. 7
CONTRACT NO.
FAA AD BRD-127
AS AD



OUTDOOR TEST RANGE EVALUATION OF AIRCRAFT PAINT PATTERNS

407910

APRIL 1962

PROJECT NO. 110-512R

PREPARED FOR

FEDERAL AVIATION AGENCY

Systems Research & Development Service

BY

APPLIED PSYCHOLOGY CORPORATION

4113 Lee Highway

Arlington 7, Virginia

TECHNICAL REPORT NO. 7

Contract No. FAA/BRD-127

OUTDOOR TEST RANGE EVALUATION OF
AIRCRAFT PAINT PATTERNS

Prepared by

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For

Federal Aviation Agency
Systems Research and Development Service
Washington 25, D. C.

This report has been approved for general distribution.

This report has been prepared by the Applied Psychology Corporation for the Systems Research and Development Service, Federal Aviation Agency, under Contract No. FAA/BRD-127. The contents of this report reflect the views of the contractor, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official policy of the SRDS or the FAA.

April 1962

Applied Psychology Corporation
Arlington, Virginia

OUTDOOR TEST RANGE EVALUATION OF AIRCRAFT PAINT PATTERNS,
April 1962

25 pp., 9 illus., 4 tables, 18 refs., Technical Report No. 7
Contract No. FAA/BRD-127

ABSTRACT

Six paint patterns representing three principles of aircraft exterior paint patterning were tested on an outdoor test range. Measures were obtained of the detectability of each pattern and the accuracy with which flight attitude could be determined from it. Eleven experienced pilots viewed four sizes of aircraft models against background panels of four different colors, under both clear and overcast skies.

Models with patterns were detected more frequently than an aluminum model, but no pattern was exceptionally more detectable than any other.

For accuracy of flight attitude determination, all patterned aircraft provided higher average scores than the plain aluminum with little difference among the several patterns. A pattern in which the fuselage was painted white on top, gray on the underside, with a red-orange fluorescent empennage was found to hold advantages indicating it would offer the greatest reliability across a variety of environmental conditions.

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ACKNOWLEDGEMENTS

The investigators wish to express their appreciation to the many persons who aided in the data collection for this study. In particular, thanks are extended to the persons who served as observers; to the contract monitor, Eugene E. Pazera; and to those who administered the tests, Wayne D. Howell and Philip R. Marshall of the National Aviation Facilities Experimental Center.

SUMMARY OF THE PROJECT

More than 85% of all mid-air collisions have occurred during VFR operations. Since in all likelihood a substantial majority of flights will continue to take place under Visual Flight Rules for some years to come, the Federal Aviation Agency in July 1959 established a program calling for comprehensive research into visual aids for preventing mid-air collisions.

The principal areas being investigated by the contractor, the Applied Psychology Corporation, are paints, exterior light systems, smoke and vapor trails, optical devices, training procedures, and a determination of those items of information needed by pilots for making reliable avoidance-maneuver decisions.

The approach consists of a progression from laboratory work, through field tests, to flight testing. Experimental studies have been conducted to derive those quantitative data regarded as prerequisite to efficient and practical field tests. The field tests have then been designed to assess promising devices and techniques through ground-based observations; as such, they served as economical screenings prior to flight tests.

In-flight evaluations have been reserved for final testing of proposed solutions and for investigating operational problems.

Technical Reports have been, and will be, issued as statements of particular experiments or analytical studies; Summary Reports will be issued as summarizations of all work done in the various broad areas of investigation (e.g., paints, exterior light systems).

The present report is Technical Report No. 7. Other reports, both published and planned for publication, are listed below:

Technical Reports

No. 1 Analysis of the Usefulness of Coded Information in Visual Collision Avoidance

No. 2 Comparative Conspicuity of Several Aircraft Exterior Paint Patterns

No. 3 Aircraft Flight-Attitude Information as Indicated by Exterior Paint Patterns

No. 4 Field Study of Threshold Ranges for Aircraft Detection and Color Identification

No. 5 Pilot Judgments of Simulated Collisions and Near Misses: A Comparison of Performance with Uncoded and Two-Tone Coded Models

No. 6, 9,
& 14 Effects of Steady and Flashing Backscatter on Foveal and Peripheral Viewing of Target Lights¹

No. 8 Flight Simulator Tests of Altitude-Coded Lights

No. 10 & 11 Pilot Judgments of Aircraft Range and Relative Altitudes: Ground-to-Air and Air-to-Air Observations

No. 12 Distance Estimation of Frequency-Coded and Uniformly Flashing Lights²

No. 13 Conspicuity of Selected Signal Lights Against City-Light Backgrounds³

No. 15 Visual Collision-Avoidance Considerations of Air Traffic Management

No. 16 Flight Tests of Altitude-Coded Aircraft Lights

Summary Reports

The Role of Paint in Mid-Air Collision Prevention

The Role of Range and Altitude Judgment in Mid-Air Collision Prevention

The Role of Smoke Trails in Mid-Air Collision Prevention

The Role of Exterior Lights in Mid-Air Collision Prevention

The Role of Optical Devices in Mid-Air Collision Prevention

¹ These three Technical Reports have been combined and replace the previously listed reports.

² This title replaces the previously listed "Evaluation of the Conspicuity of Aircraft Smoke Trails: A. Ground-to-Air Observations" which will not be published.

³ This title replaces the previously listed "Evaluation of Conspicuity of Aircraft Smoke Trails. B. Air-to-Air Observations" which will not be published.

TECHNICAL REPORT NO. 7

OUTDOOR TEST RANGE EVALUATION OF

AIRCRAFT PAINT PATTERNS

Background

Of the many purposes which aircraft exterior paints serve, pilots generally feel that two would be particularly useful in avoiding mid-air collisions during VFR flight. Paints applied in appropriate patterns might increase the conspicuity of aircraft, and they might indicate the sighted aircraft's flight attitude, knowledge of which might be useful in deciding on collision-avoidance maneuvers.

In recent years, there have been many attempts to apply paints in ways that would accomplish these purposes. Among available paints, certain fluorescent coatings have received considerable publicity. It has not been generally agreed, however, that presently available fluorescent paint is sufficiently more visible than other surface coatings to justify its comparatively high cost and complicated application.

There have been a number of studies which support the use of fluorescent paint, particularly that in the red-orange wave lengths. Laboratory studies carried out as part of this research program suggest some positive correlation between the amount of fluorescent paint and conspicuity, as determined by paired-comparison judgments (Applied Psychology Corporation, 1961a). Field observations of operations at Washington National Airport demonstrate that fluorescent paints in the yellow-orange-red portion of the spectrum can be identified more than twice as far as colors (throughout the spectrum) of ordinary paints (Applied Psychology Corporation, 1961c). Similar results were found by Fitzpatrick and Wilcox (1960) in a study of detection and recognition ranges of small circular targets. A yellow-orange fluorescent was recognized at greater distances than either non-fluorescent yellow, or international orange. A flight study at the CAA Technical Development Center, Indianapolis (Howell, 1958), indicated that fluorescent paint improves daytime conspicuity appreciably and helps the pilot detect aircraft at low altitudes in the proximity of airports, particularly when the aircraft are viewed at short distances and with the ground as a background.

A flight study performed for the U. S. Coast Guard (Hodgson, 1959) used a "high visibility" aircraft paint design, with black on shadow areas and undersurfaces, white on upper surfaces, and fluorescent red or orange on one or two large

sunlit areas. The author reports this combination of brightness contrast and color contrast to be valuable. In a field study of patterns on airdrop test vehicles (Anders & Lenz, 1957), a similar combination of brightness contrast and color contrast was found beneficial. Standard practice had been to paint these vehicles in alternate quarters of orange and white, a pattern which could not be satisfactorily photographed. Extensive field observation and photography indicated that a pattern comprised of areas of white, flat-black, and fluorescent-orange paint in most beneficial.

Fluorescent paints were found advantageous in detecting targets at sea (Halsey, Curtis, & Farnsworth, 1955).

A series of laboratory studies for the Naval Air Material Center compared the visibility of fluorescent and nonfluorescent paints (Crain & Siegel, 1960; Siegel, 1961; Siegel & Crain, 1960, 1961). Fluorescent paints were found to have certain conspicuity advantages. The chief methods used in these studies were retinal-perimetry and tachistoscopic-threshold measurements.

Orange fluorescent paint was found to be the best color for hunters to wear so as not to be mistaken for deer (Richards, Woolner, & Panjian, 1960).

On the other hand, there have been studies which, while not contraindicating fluorescent paint, certainly do not completely support the studies cited above. Ground-to-air and air-to-air flight tests designed by Applied Psychology Corporation and conducted by personnel of the National Aviation Facilities Experimental Center (NAFEC) showed no difference in detection of aircraft with fluorescent paint and those without it (Marshall, 1962; Sunkes, 1962). In ground-to-air tests, DC-3 target aircraft flew prearranged courses, and observers were given brief glimpses of the aircraft as they crossed each of five visual checkpoints located 1.3 to 7.3 miles from them. Of 300 observations there were 78% detections of both the fluorescent-painted aircraft and the aircraft without fluorescent paint.

In air-to-air tests two Beech Bonanza aircraft, one painted with a fluorescent pattern, the other without special treatment, flew together in a triangular course. A third aircraft, carrying an observer, flew the course in the opposite direction. The observer indicated when he first saw one or both of the aircraft, and again when he could identify which aircraft displayed the fluorescent color. There were no significant differences between the number of times the fluorescent and nonfluorescent aircraft were first detected, nor between the detection ranges for the two aircraft.

In the above-mentioned field observations of operations at Washington National Airport, in ground-to-air and air-to-air observations conducted at Wright Air Development Center (Baker, 1960), and in flight tests conducted by United Air Lines (Skeen, 1958), there were no differences between threshold detection ranges for aircraft with fluorescent paint and those with nonfluorescent paint. In all of these studies detection ranges were usually much greater than the ranges at which color could be seen, hence it was not possible for color to provide an advantage. (Fitzpatrick & Wilcox, 1960, found the same result using small circular targets at closer ranges.) Furthermore, while in the National Airport study fluorescent paint colors were identified on the average twice as far as ordinary paint colors, individual identification ranges of nonfluorescent paint colors sometimes exceeded those of fluorescent colors (probably due to specific combinations of sunlighting, cloud condition, color, etc.).

In many of the above studies, the main interest was the effect of fluorescent paint per se, rather than optimum paint patterning. Where aircraft were used, some "convenient" pattern was selected; but with few exceptions, examination of patterning for conspicuity and attitude determination was not the main (in some cases, not even an incidental) concern. As a result, some of the research studies performed in the present program examined the effects of patterning.

Laboratory tests (with no relative motion of the target) indicated that, in general, paint patterning is not a valuable aid to flight attitude determination (Applied Psychology Corporation, 1961b). While some patterns scored better than others in specific viewing situations, the differences were not statistically significant, nor were they worthy of dependence in a practical sense. Flight simulator tests which introduced relative motion corroborated this finding, and pilot-subjects indicated they felt they had depended largely on relative motion (rather than surface patterning) to make decisions regarding collision courses (Applied Psychology Corporation, 1961d).

Wagner and Blasdel (1948) report an extensive laboratory study evaluating 37 variations of paint patterns which utilized a weighted score reflecting the accuracy with which observers could identify heading. Using this measure (essentially an indication of how well flight attitude can be determined), a glossy sea-blue enamel applied to the trailing halves of the empennage and wing surfaces of an aluminum aircraft model was found most efficient.

Purpose

This study investigated the merits under field conditions of three principles of paint patterning which had been found

beneficial to conspicuity in laboratory studies: (a) differentiating top and bottom of the aircraft by means of brightness contrast, (b) extending the area of red-orange fluorescent paint, and (c) massing (rather than splitting up) the area of red-orange fluorescent paint (Applied Psychology Corporation, 1961a). The fluorescent paint was placed on the empennage, because in earlier laboratory work this location yielded better attitude-determination scores than several others (Applied Psychology Corporation, 1961b). Also, certain operating considerations seem to indicate this to be a suitable location (minimal reflection into pilots' or passengers' eyes, relative ease of application and maintenance).

These patterns provide elements for both brightness contrast and color contrast. While research to date may not prove conclusively the conspicuity value of fluorescent paint in flight operations, there seems little doubt that as a color it can be recognized further than can other types of paint (Applied Psychology Corporation, 1961c; Fitzpatrick & Wilcox, 1960). Hence, red-orange fluorescent paint was used to provide the color contrast in these patterns.

Method

Stimulus Patterns

Six paint patterns applied to model aircraft were used to test the three principles (Fig. 1), and an all-aluminum model was used as a control.

The principle of differentiating top and bottom of the aircraft by use of brightness contrast is represented by the patterns on the right half of Fig. 1. These patterns have the top painted white, and the underside painted gray. The patterns on the left half of Fig. 1 do not have this differentiation. The patterns in the middle row represent the principle of increasing the area of fluorescent paint (which they do compared to the patterns in the first row).

The patterns in the bottom row represent the principle of splitting the extended area up into smaller areas. This extended area is transferred to the wings. The total paint area on the top (or bottom) side of the wings is equal to the area between the empennage and the trailing edge of the wing when the fuselage is viewed broadside.

The white paint (Krylon flat white) had a reflectance of about 75%, the gray (Krylon light gray) a reflectance of about 7%. A simple reflectance value cannot be stated for the fluorescent paint (Krylon fluorescent red-orange, ANA color No. 633), but it conformed to military specification MIL-P-21600 (AER) and had a clear overcoating.

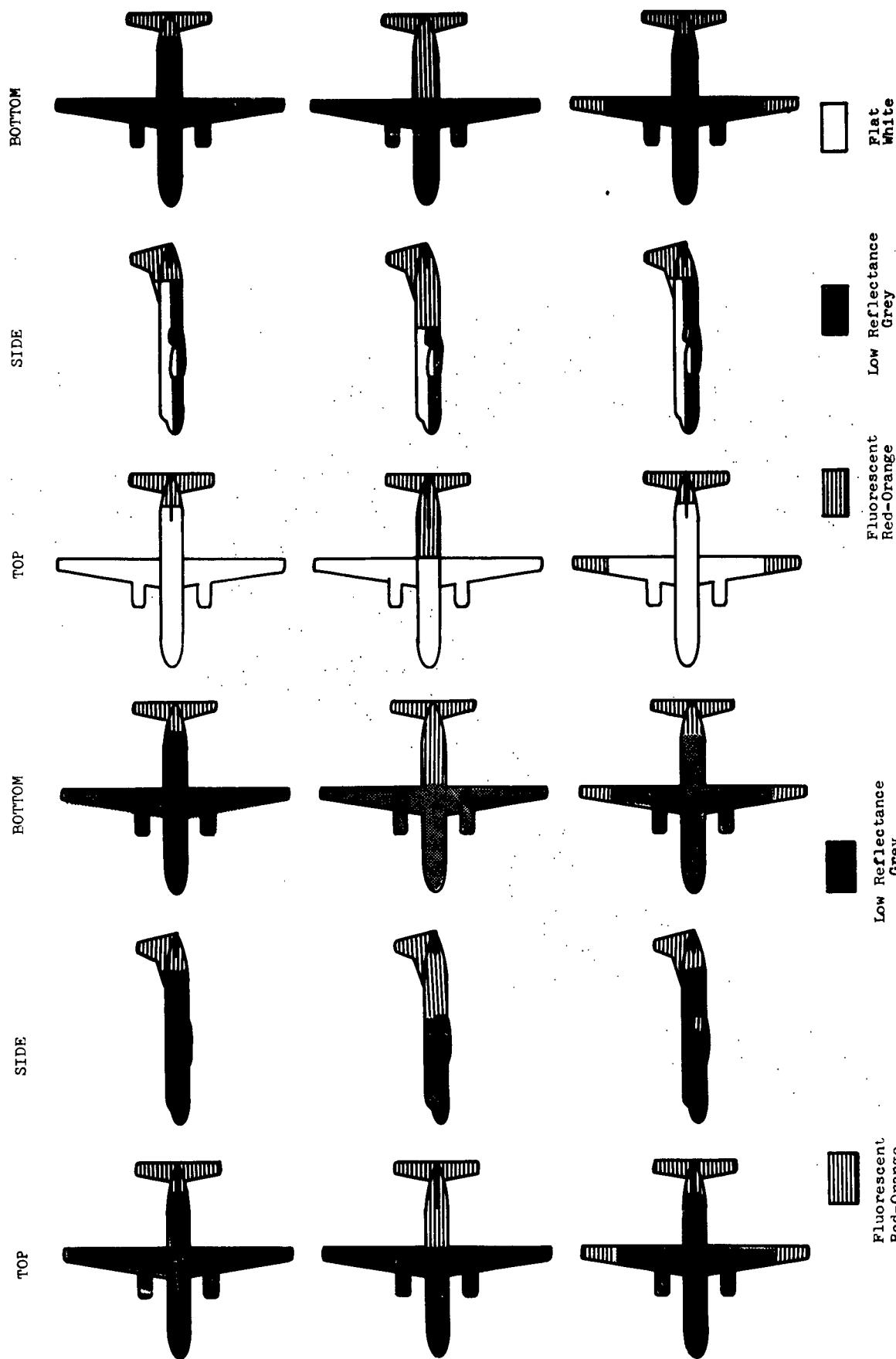


Diagram illustrating various paint patterns evaluated on aircraft.

Fluorescent Red-Orange

Low Reflectance Grey

Fluorescent Red-Orange

Low Reflectance Grey

Flat White

Apparatus

General description. The experiment was conducted at the National Aviation Facilities Experimental Center Visibility Test Range, Warren Grove, New Jersey. Facilities consisted of an observation building and, at a distance of 300 feet, a specially constructed stimulus-presentation area consisting of targets, backgrounds, and a supporting structure. Observers viewed the stimulus area from the second floor of the observation building. Targets were models of twin-engine aircraft. Each single stimulus presentation consisted of one model, set at a certain flight attitude and viewed against one of four background colors by six observers. Each observer responded by positioning a response model in the attitude which he believed to correspond to that of the target model. By electrical connections, it was possible for a recorder to read the response on a remote display panel. A telephone intercommunication system with headsets allowed the experimenters to communicate between stimulus area and observation building.

Targets and mounting. Targets were wooden models of twin-engine aircraft as shown in Fig. 2. Sizes were: (a) 6" wingspan, 4-7/8" length; (b) 9" wingspan, 7-1/3" length; (c) 13-1/2" wingspan, 11" length; (d) 20-1/4" wingspan, 16-1/2" length. These were not models of actual aircraft, but were instead stylized representations of a twin-engine transport aircraft.

Heading, pitch, and roll of the target aircraft were set in by means of nine forked rods of 3/16" diameter. These were inserted in a 12"-long tube (1/4" diameter), which was suspended sturdily in front of the backgrounds by means of 1/32"-diameter cables (Fig. 2). The forked part was bent so that it allowed the model to be displayed in one of the three pitches used (level, 15° up, 15° down), and also in one of the three rolls (level, 30° right, 30° left). To set a target's heading, an arm on the rod was inserted into one of 12 holes drilled around a .04" thick disc at 30° intervals. The display apparatus was painted very light gray and was virtually invisible from the observation building.

Backgrounds. Figure 3 presents an over-all view of the stimulus presentation area with target display apparatus and backgrounds. Backgrounds were four 12'x12' plywood panels, mounted back to back on two frames. Frames were raised vertically into position by a winch. The back-to-back panels pivoted horizontally within their frame, permitting rapid changing. Backgrounds were painted dark green (Lucas Luco Tex, Velvet Green), light tan (Gold Bond Desert Buff), white (Lucas Luco Tex), and light blue (one part Lucas Luco Tex Iroquois Blue to four parts Lucas Luco Tex Tinting White).



Fig. 2. Twenty-inch wingspan target model and display apparatus.

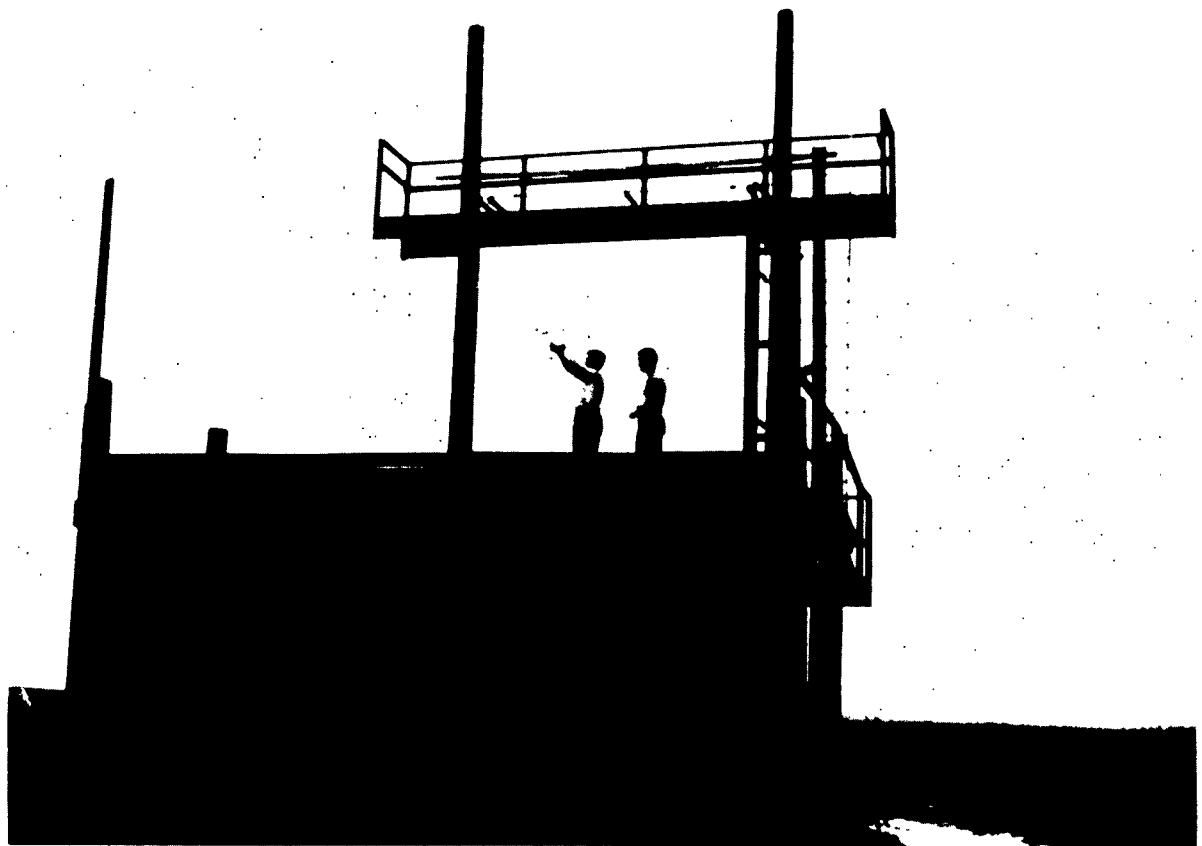


Fig. 3. Stimulus presentation area.

Observer response equipment. An observer position with its response apparatus is shown in Fig. 4, while Fig. 5 shows the experimenter position. An aluminum model aircraft with 6" wingspan, similar in design to the target models, was mounted on a pedestal about 14" in front of each observer. On the base of the pedestal holding the model were buttons indicating "not sighted," "sighted, attitude not determined," and "sighted, can determine attitude." Each button when pressed actuated a corresponding light on a readout panel at the experimenter's position, permitting him to record each observer's response. The response model could be set at any attitude used in the experiment, and the settings actuated lights on the experimenter's readout panel indicating the azimuth, pitch, and roll positions.

To limit the observer's view to the target and background, a plywood screen was placed about two feet in front of him. At eye level there was an 8"x10" opening which, between presentations, was covered by a shutter actuated by an electrically timed mechanism, thus keeping viewing time constant for all trials and subjects.

A spot photometer in the observation building measured the brightness of each background panel throughout the series of problems.

Observers

Observers were 11 experienced pilots, all of whom had visual acuity of at least 20/20 with correction, and normal color vision.

Procedure

Prior to actual testing, observers were given a comprehensive one-hour familiarization. The experimenter outlined the background and purpose of the study and distributed individual copies of a diagram of the seven paint patterns. Differences and similarities of the patterns were pointed out.

An operating crew of seven was required. In the observer building, two men recorded answers and one recorded background brightness readings. At the background location, one man changed backgrounds, two men changed models and attitudes, and one man coordinated by telephone with the operating personnel in the observer building.

Problems were presented in sets of four. Each set used the same background, pattern, and model size, but the problems within it used different attitudes. The 108 flight attitudes possible with the model mount had been previously classified into five categories on the basis of the similarity of the silhouettes. Difficulty of perceiving the attitude was believed to be more similar among the attitudes within a category



Fig. 4. Observer position and response apparatus.

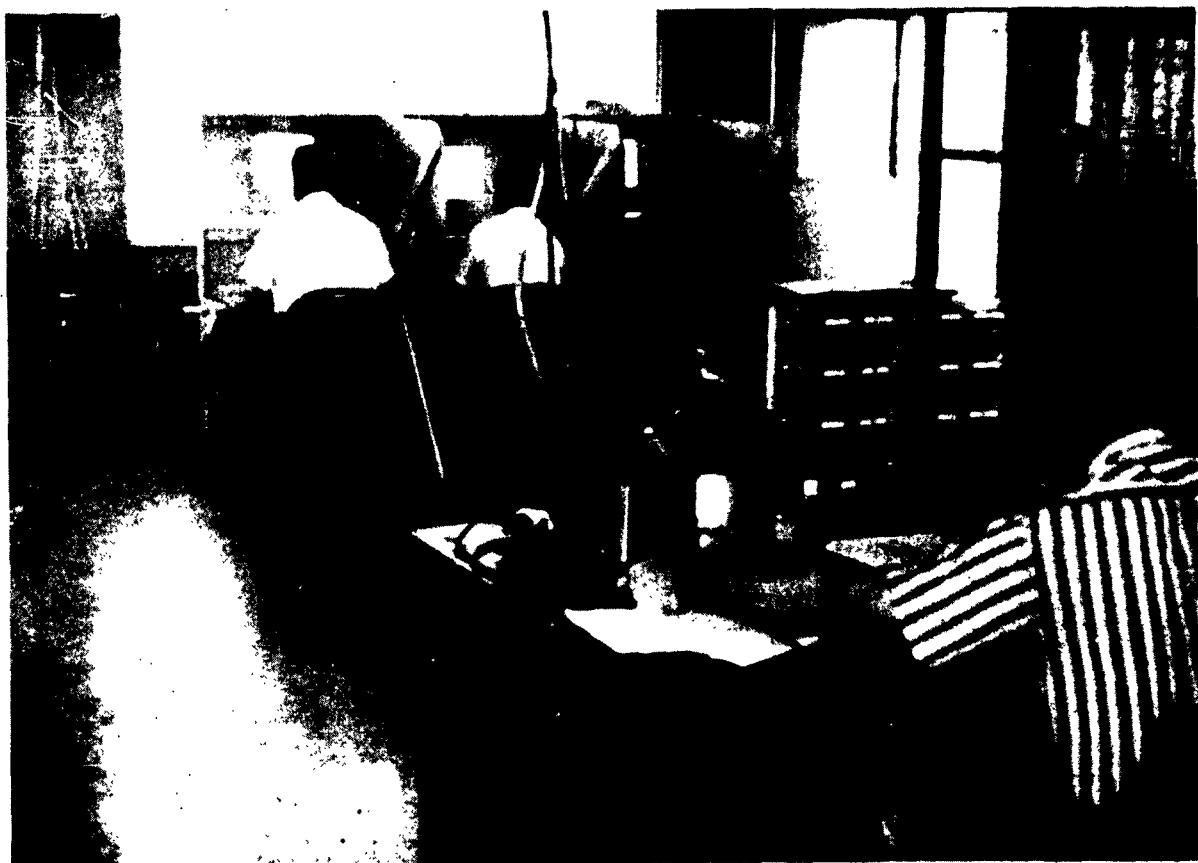


Fig. 5. View of observation room showing observers in position, experimenter (A), response readout panels (B), and timer for shutters (C).

than among attitudes in the different categories. For example, head-on and tail-on views were considered to be of similar difficulty, and this difficulty was considered to be different from that presented by the broadside views. The four attitudes in each set were selected randomly from these five categories. The sets were then randomized and presented to the observers by prearranged schedule.

Before presenting each set, the experimenter announced the pattern, so that subjects could check their pattern diagrams. The viewing shutter opened for three seconds, during which subjects observed the model's attitude. After the shutter closed, the subjects were given about 30 seconds to record their observations. Recordings consisted of pressing one of the buttons and, if they could tell the attitude, adjusting the response model.

Judgments were recorded by the experimenter on precoded answer sheets (Fig. 6). A correct heading was scored four points; a miss by one clock position in either direction was scored two points; other headings were given no points. Correct pitch was scored two points; correct roll was scored three points; if a roll was judged in the opposite direction, it was scored one point. However, if level flight was seen as roll, or if a roll was seen as level flight, no score was given. The observer was told that if he could determine only a partial attitude, he was to indicate that part and estimate the rest as accurately as possible.

Each of the two experimenters scored three subjects. One of them also activated the timer, cleared the readout panel, and maintained voice communication with personnel changing backgrounds and models.

To acquaint observers with experimental procedures, five practice problems using the aluminum model were presented. These same problems were used both for pretest familiarization and as a refresher before the first session. Before each succeeding session, ten different practice problems were given. In all problems, the experimenter announced the correct attitude after responses had been made.

All observers completed the experimental problems on both overcast and clear days. Observations on clear days were made in the morning hours, so that the backgrounds and targets, which faced the east, were never in shadow.

Sessions averaged about 2-1/2 hours, with a five-minute break about every 25 minutes.

Date _____ Subject # _____ Pattern _____ Size _____
 Name _____ Background _____ Weather _____

	Detection	Heading (4,2,0)	Pitch (2,0)	Roll (3,1,0)	H	P	R
1	N S D	A B C D E F G H I J K L	A B C	A B C	— + — + — = —		
2	N S D	A B C D E F G H I J K L	A B C	A B C	— + — + — = —		
3	N S D	A B C D E F G H I J K L	A B C	A B C	— + — + — = —		
4	N S D	A B C D E F G H I J K L	A B C	A B C	— + — + — = —		
Total					Total		

Fig. 6. Answer sheet for one set of four problems. Under "heading," letters A through L are clock positions 12 through 11; pitch, A, B, C, are up, level, down; roll, A, B, C are left, level, right. Letter "N" on left is for no sighting, and letter "S" on left is for detected, but could not tell attitude. Letters "H, P, R" on right were for scoring heading, pitch and roll separately with a total.

Results and Discussion

Aircraft Detection

Since in almost all cases the observers were able to sight the models, the complete data analysis originally planned for detection scores was not carried out; with so few misses, there was little differentiation on which to base any conclusion. To introduce some spread of scores, the original definition of simple "detection" was modified. There was some question whether an observer unwilling to estimate the model's attitude had actually seen the model (or that he would have seen it had he been operating an aircraft), and consequently detection score was redefined to include only sightings for which the subject was willing to attempt to determine attitude. Further, these scores were analyzed only to determine the effects of the six individual patterns, three patterning principles, and weather conditions. Under clear skies there were 91% detections, under cloudy skies, 90%, despite the rather sizeable differences in background brightnesses as shown in Table 1. In Table 2, the row totals show the results for fuselage treatments, the column totals the results for the fluorescent-paint treatment, and the Individual cell entries the scores for the six individual patterns. None of these detection scores has any practical significance, except that all of the paint treatments yielded higher scores than the aluminum-painted model. The present findings do not confirm the laboratory indications that patterns with white-and-gray fuselage and fluorescent paint extended to the trailing edge of the wing would be detected most frequently.

Accuracy of Attitude Determination

The experimental design permitted examination of how accuracy scores varied with all possible combinations of the variables and with every level of each. Since there were so many levels (28, yielding 2464 individual conditions), nearly all main effects and interactions showed statistically significant differences. As a result, mean accuracy scores were inspected to determine differences which appeared to be great enough to have practical (as opposed to statistical) significance.

Table 3 contains mean accuracy scores for individual patterns and principles. As with detection scores, there is little differentiation among the patterns. The most meaningful difference is that between patterned aircraft as a group and the aluminum model; again, none of the patterning principles yielded any noteworthy differences, but all were better than no pattern.

Table 1

Background Brightness Measures (Footlamberts)

Background	Percentile ^a			Clear			Overcast		
	25%	50%	75%	25%	50%	75%	25%	50%	75%
Green	774	854	930	104	155	311			
Blue	2210	2779	3096	297	381	541			
Tan	2197	2637	2950	279	352	727			
White	3653	4645	5208	455	612	1150			

^a These are the readings below which 1/4, 1/2, and 3/4 of the brightness measures fell.

Table 2

Detection Scores for the Paint Patterns Tested

Paint on Fuselage and Wings	Fluorescent Area Coverage ^a			Combined Fluorescent Treatments
	Empennage Only	Empennage and Tail Section to Trail- ing Edge of Wing	Empennage and Wingtips	
All Gray	89	91	93	91
White Top Gray Bottom	90	90	92	90
Combined Fuselage Treatments	90	90	92	

^a The aluminum model was detected 82% of the time.

Table 3
Mean Accuracy Scores for the Paint Patterns Tested

Paint on Fuselage and Wings	Fluorescent Area Coverage ^a			Combined Fluorescent Treatments
	Empennage Only	Empennage and Tail Section to Trail- ing Edge of Wing	Empennage and Wingtips	
All Gray	21.9	23.9	23.7	23.2
White Top Gray Bottom	24.5	22.1	23.5	23.4
Average of Fuselage Treatments	23.2	23.0	23.6	

^a The aluminum model had a mean accuracy score of 18.7.

Analysis of variance reveals that accuracy scores for patterns vary as a function of background (Fig. 7). Two items are of interest: first, scores across the four backgrounds spread quite widely for some patterns, narrowly for others; second, one background produced lower mean scores for some paint patterns than for the unpatterned aluminum model.

Interaction between patterns and backgrounds was the only interaction (involving patterns) with any practical implication. Scores for patterns were not found to vary significantly with clear or overcast skies. Nor did scores for patterns vary differentially as a function of size of aircraft, indicating that no pattern held any advantage for close or distant ranges, or for large or small aircraft at the same range (both situations were simulated by the various sizes of aircraft models).

Accuracy scores did vary, however, with model size (Fig. 8). Also, individual observers differed in ability to determine attitude; some averaged little more than half, while the best averaged over two-thirds of the total 36 points. Scores were not greatly different for each of the four backgrounds, nor for the two weather conditions.

Selected Paint Pattern

The investigators believe that if maximum collision prevention benefit is to be derived from any paint pattern, it should be a standardized pattern. Standardization will reduce ambiguities and thus result in faster collision-avoidance decisions.

Results of this and other studies (Applied Psychology Corporation, 1961a) indicate that a paint pattern of some kind on the exterior surfaces of the aircraft seems more beneficial than a plain aluminum surface. Within the paint patterns chosen for study in this experiment, there was little differentiation. This may be because the patterning principles studied had all shown promise in prior investigations. However, the pattern with gray-and-white fuselage and red-orange fluorescent empennage seems to hold small advantages over the other patterns on a number of points. Taken together, these advantages appear to support the selection of this pattern in principle.

It had the highest mean accuracy score and the narrowest spread of mean scores across the four backgrounds (Fig. 7). While other patterns had higher scores against certain backgrounds, they also had lower scores against others, indicating the white-and-gray fuselage, red-orange fluorescent empennage provides more reliable information.

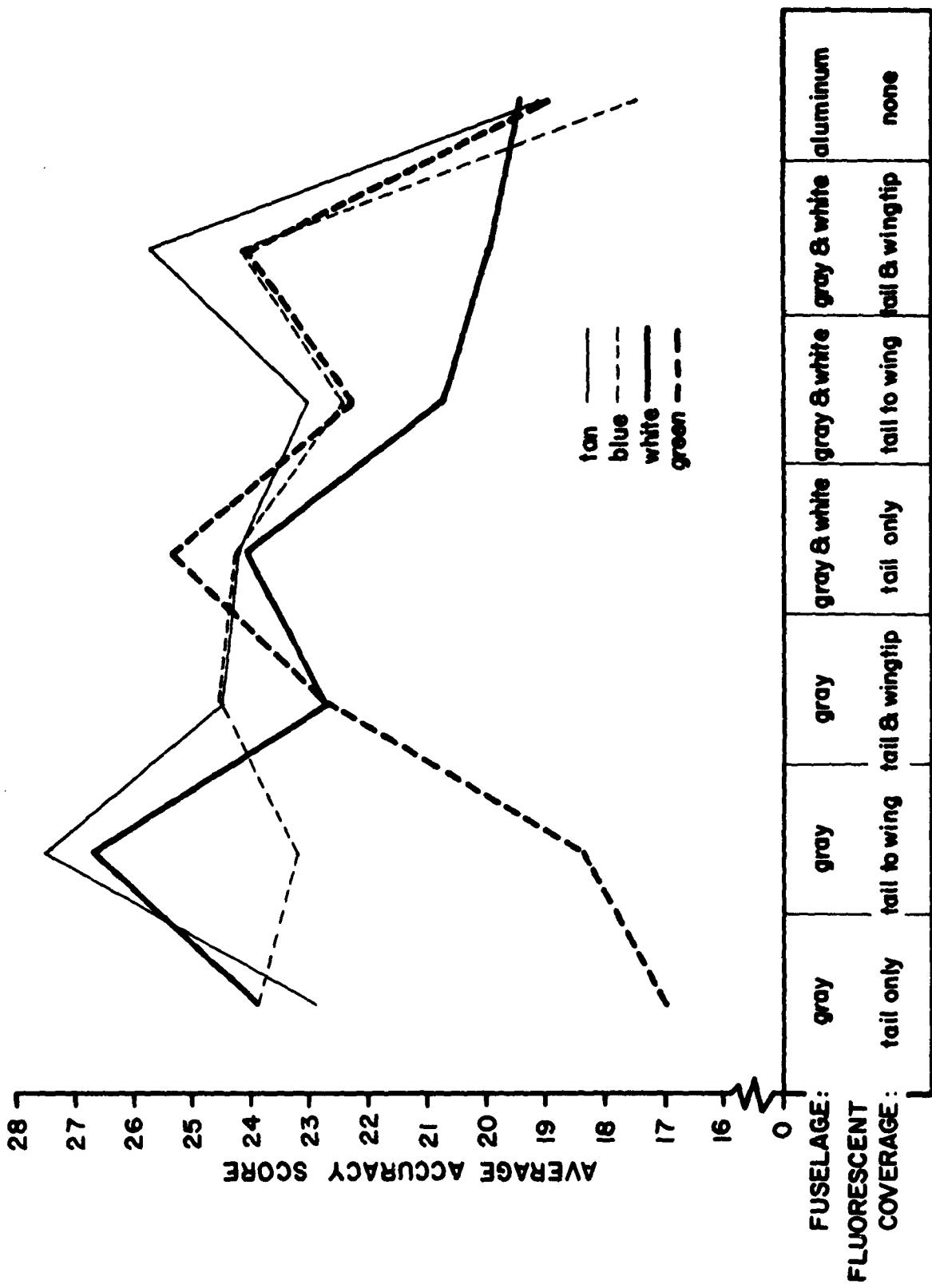


Fig. 7. Accuracy scores of each paint pattern as a function of the background against which it was viewed.

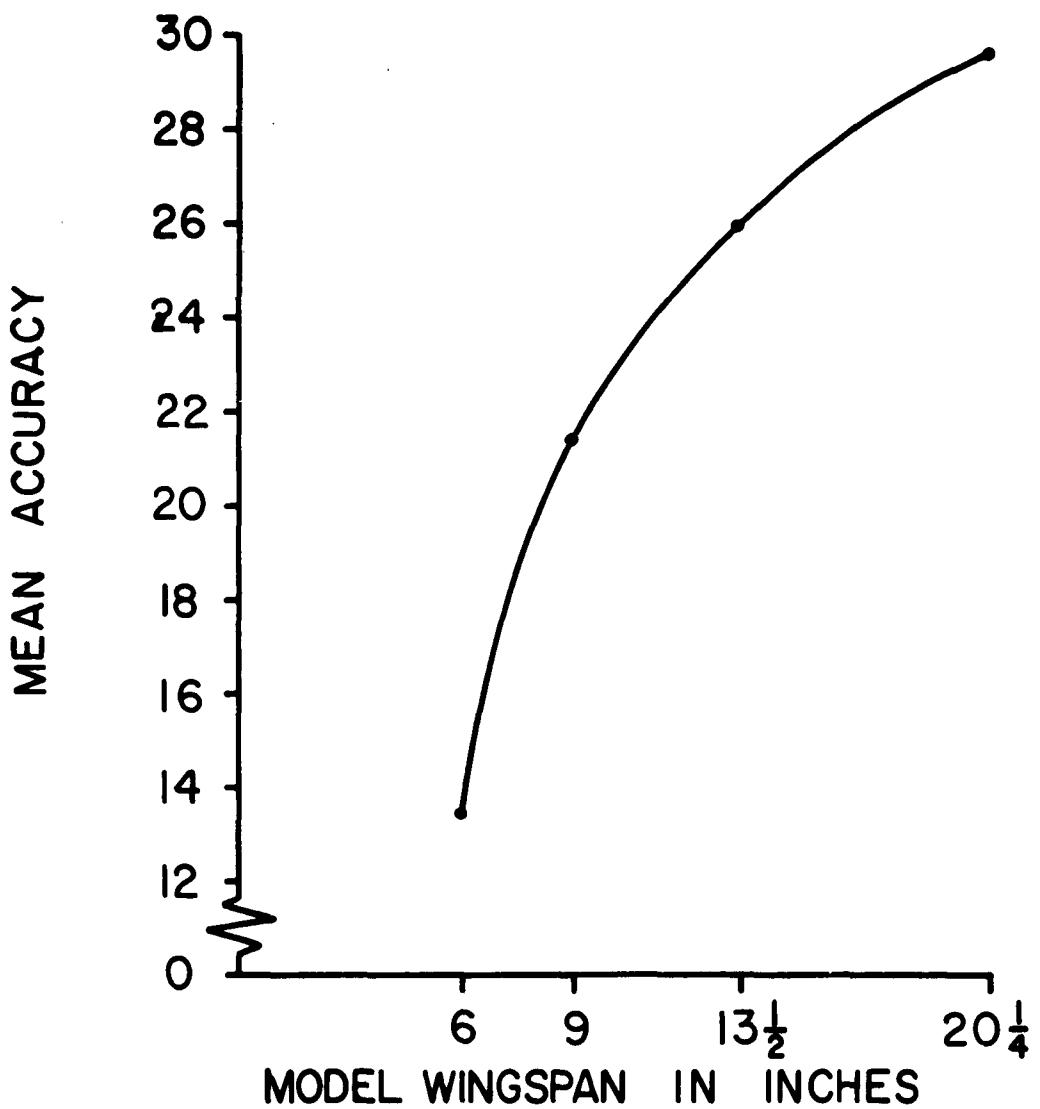


Fig. 8. Accuracy scores as a function of size of model.

This pattern also scored best in percentage of correct responses to heading, pitch, and roll settings (Table 4).

It had the smallest spread of azimuthal errors. There were 11 possible azimuthal position errors; the fewer positions named, the more reliable is the information the pattern provides. Even though one other pattern (all-gray fuselage, red-orange fluorescent empennage) had a lower number of erroneous positions assigned to it (Fig. 9), it also had a lower over-all accuracy average and a greater spread of accuracy scores against the four backgrounds (Fig. 7).

Strict adherence to the white, gray, red-orange fluorescent combination is probably not required. What seems important is that the color used on the top-side of the fuselage be one of high reflectance, the color on the underside a low reflectance, and the color on the empennage an unnatural one to provide color contrast at as great a distance as possible across a variety of backgrounds.

Summary and Conclusions

Six paint patterns representing three principles of aircraft exterior paint patterning were tested on an outdoor test range. Measures were obtained of the detectability of each pattern and the accuracy with which flight attitude could be determined from it. Eleven experienced pilots viewed four sizes of aircraft models against background panels of four different colors, under both clear and overcast skies.

Models with patterns were detected more frequently than an aluminum model, but no pattern was exceptionally more detectable than any other.

For accuracy of flight attitude determination, all patterned aircraft provided higher average scores than the plain aluminum. Again, there was little difference among the several patterns. The pattern with the fuselage painted white on top and gray on the underside and empennage painted red-orange fluorescent was found to hold the following advantages: (a) highest average accuracy score; (b) least spread of scores across several backgrounds; (c) highest percentage of correct settings of heading, pitch, and roll; (d) least spread of azimuthal errors. This pattern would seem to offer the greatest reliability across a variety of environmental conditions.

Table 4
 Average Per Cent Correct of Each
 Pattern for the Three Attitude Positions

Pattern		Attitude Position		
Fuselage	Fluorescent	Azimuth	Pitch	Roll
All Gray	Tail Only	42	66	66
All Gray	Tail to Wing	52	71	68
All Gray	Tail and Wings	46	63	70
White Top Gray Bottom	Tail Only	59	72	79
White Top Gray Bottom	Tail to Wing	45	64	68
White Top Gray Bottom	Tail and Wings	52	70	73
Aluminum	None	36	66	67

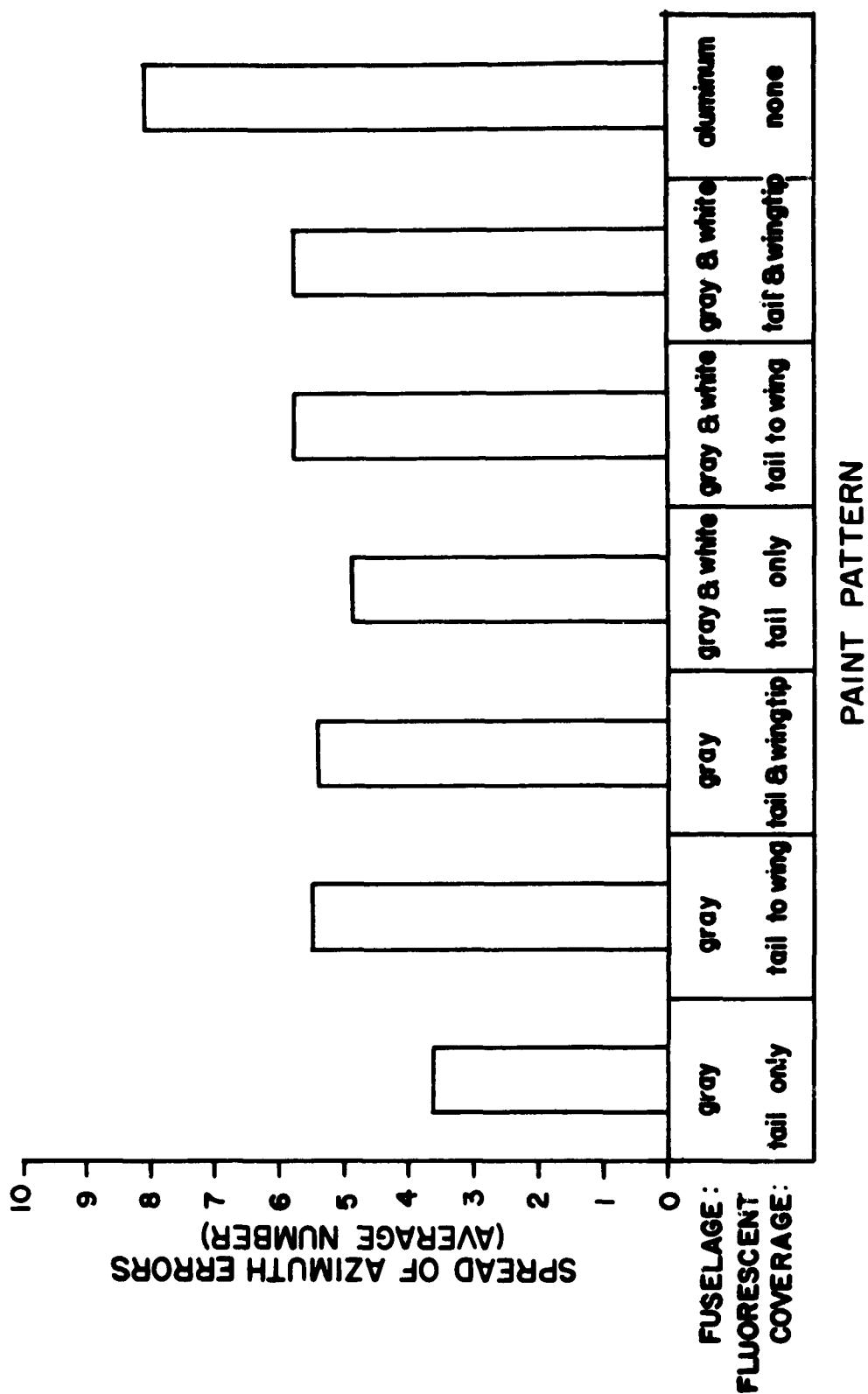


Fig. 9. Average number of azimuthal position errors for each paint pattern.

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